

# Patient Selection for Cardiac Surgery in Left Ventricular Power Failure

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• Nineteen patients in acute left ventricular power failure following acute myocardial infarction were given support with intra-aortic balloon pumping and underwent cardiac catheterization. Hemodynamic response to diastolic augmentation, results of left ventriculography, and observations of selective coronary arteriography were evaluated to determine which patients could survive without operation, which would require operation to survive, and which could be predicted not to survive operation. Of ten patients who underwent operation, three were long-term survivors. Two patients predicted to have a good prognosis without surgery did survive. Of three patients who had been determined to require operation but did not undergo it, two died in the hospital and one a month later. The four patients whose conditions were considered inoperable died in the hospital. The results indicate that current methods of predicting the need for corrective surgery are relatively accurate and that the rate of survival in surgically treated patients may be increased.

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The results of conventional management of acute severe left ventricular power failure (LVPF) have been extremely poor, with a mortality estimated at 85% to 100%.<sup>1,2</sup> The advent of the intra-aortic balloon pump (IABP)<sup>3-6</sup> has made it possible to assist these patients temporarily, but the effect on survival statistics has been a disappointment.<sup>7</sup> As a result, our standard protocol has been revised to adopt a more aggressive surgical approach. The present study was designed to evaluate our ability to select surgical candidates and to judge what impact operation has had on survival.

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## SUBJECTS AND METHODS

Between 1967 and 1974, eighty-five patients in acute severe LVPF or medically intractable cardiogenic shock following acute myocardial infarction were assisted by IABP. The first 42 patients were given conventional medical treatment and were required to fulfill strict criteria of intractable cardiogenic shock.<sup>8</sup> In the remaining 43 patients, the balloon pump was inserted as rapidly as possible following the diagnosis of severe LVPF. Severe LVPF was defined as a central aortic pressure below 90 mm Hg or 75% of the previous hypertensive state, a urine output of less than 30 ml/hr, rales in the lungs, usually an S3 gallop, sinus tachycardia, chest x-ray film evidence of congestive heart failure or pulmonary edema, and arterial hypoxemia.

Since 1971, patients less than 70 years of age whose circulatory status required both IABP and vasopressor therapy for stabilization for periods of 4 to 24 hours after the balloon was inserted were referred for cardiac catheterization to determine whether surgical correction of the cardiac lesion or lesions might be appropriate. Patients whose conditions could not be stabilized with assisted circulation and those who required massive doses of vasopressors were not considered candidates for surgical intervention.

Nineteen patients were brought to the cardiac catheterization laboratory. The average age was 57.3 years. The hemodynamic data obtained at bedside included the pulmonary capillary wedge pressure; pulmonary artery systolic, diastolic, and mean pressure; right atrial pressure; the arterial venous oxygen difference; and central aortic pressure. Dye dilution cardiac outputs were obtained in some cases. The left ventricular work index was calculated, assuming a value for oxygen consumption based on body surface area. In the cardiac catheterization laboratory, additional hemodynamic data included dye dilution cardiac output, first derivative determination, and left ventricular end-diastolic and filling pressures. Measurements were taken with the intra-aortic balloon in use and five minutes after its discontinuation.

The left ventricle was then injected with 30 to 40 ml of diatrizoate meglumine (66%) and sodium (10%) (Renografin-76). Cinefluorography was done in a 30° right anterior oblique projection with the assist device functioning. Diastolic and systolic chamber areas were determined by planimetry, and the ejection fraction

was calculated. The ventricular outline was divided into five segments (anterobasal, anterolateral, apical, diaphragmatic, and inferobasal), and the relative contractility of each segment was evaluated. Mitral regurgitation was evaluated when present, and in cases of suspected rupture of the interventricular septum, a left anterior oblique ventriculogram was obtained to demonstrate shunting of contrast material. Coronary arteriograms were performed by means of percutaneous puncture of the femoral artery in most cases, but occasionally through a brachial arteriotomy. Multiple injections of diatrizoate meglumine (66%) and sodium (10%) were made in different oblique projections with a combination of cinefluorographic and photofluorographic 105-mm spot-film techniques. The coronary arteries were subsequently examined to demonstrate their anatomy and to evaluate the vessels for bypass surgery.

Patients deemed suitable candidates were operated on with such procedures as mitral valve replacement, repair of a ruptured septum, infarctectomy, or coronary bypass surgery. Many patients had combinations of these surgical procedures. Prior to 1973, patients whose conditions were considered inoperable were assisted by IABP for long periods of time (several weeks), but since then, assist has been terminated 48 to 96 hours following catheterization. Those patients who lived and were discharged from the hospital were considered survivors.

### HEMODYNAMIC DATA AND ANGIOGRAPHIC RESULTS

The initial or base-line hemodynamic data in this group of patients reflected the severity of the cardiac decompensation. All patients at basal state prior to assistance, in addition to hypotension, oliguria, and central venous pressure of more than 10 cm H<sub>2</sub>O, had pulmonary capillary wedge pressures greater than 22 mm Hg, a cardiac index less than 2 liters/min/sq m, arteriovenous oxygen consumption differences of greater than 6 vol%, and pulmonary artery oxygen saturations of less than 60%. Some patients had a disproportionate degree of right ventricular failure due to inferior wall infarction and involvement of the right ventricle. The left ventricular work index was less than 3.5 kg-m/min/sq m in all but two patients. In a few patients with unexpectedly low end-diastolic pressure of the left ventricle, left ventricular dyskinesia was demonstrated. The low end-diastolic pressure in the face of poor ventricular function suggested increased compliance secondary to the left ventricular dyskinesia.

Seventeen of the 19 patients underwent left ventriculography. Two patients did not exhibit sufficient improvement in their hemodynamic status to allow the risk of large bolus injections of contrast medium. Another patient had premature ventricular contractions during the injection, and a reliable ejection fraction could not be obtained. A second injection was not attempted because of a sudden sharp rise in the pulmonary capillary wedge pressure. The ejection fraction was 37% or less in 16 patients and less than 30% in 13. Ten patients had mechanical defects that complicated coronary artery disease: three patients had rupture of the interventricular septum; four had serious mitral regurgitation, probably secondary to papillary muscle dysfunction or rupture; and localized dyskinesia was present in five patients, either alone or in conjunction with other mechanical defects.

All patients had selective coronary arteriography. The

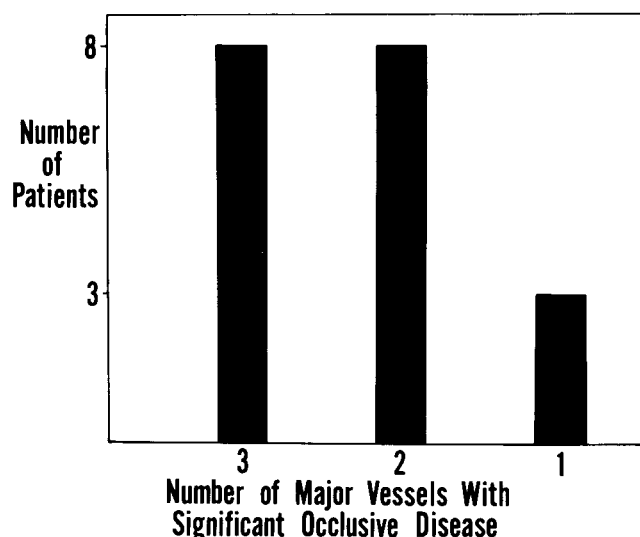


Fig 1.—Major coronary vessels with serious occlusive disease in 19 patients with acute severe left ventricular power failure.

distribution of important coronary arterial lesions is shown in Fig 1 and 2. Sixteen of 19 patients had serious disease in at least two major vessels, and three patients had single-vessel disease. Two with single-vessel disease had total proximal occlusion of the anterior descending artery, and another had total occlusion of a large, dominant right coronary artery. Not included in Fig 1 and 2 are two instances of 90% or greater stenosis of the left main coronary artery. Additional important lesions involving anterolateral branches of the anterior descending artery and lateral and posterolateral branches of the left circumflex artery were present in many instances. There were no complications related to the catheterization, but sudden severe elevation of left ventricular end-diastolic and pulmonary capillary wedge pressures was common after left ventriculography.

### SELECTION OF PATIENTS FOR SURGERY

The physiologic response to IABP, the relative amount of viable myocardium as determined by ventriculography and electrocardiography, and the anatomy of the coronary arteries were evaluated in each patient. The severity of the disease as reflected by physiologic data in the basal state was not considered a contraindication to surgery. Since all patients in this group had responded positively to balloon pumping, they were considered to have potentially reversible myocardial deficits. The relative response to IABP was regarded as an indicator of the amount of myocardial reserve.

Two patients had a particularly dramatic response to assistance. The first had an initial systolic blood pressure of 64 mm Hg, a pulmonary arterial pressure of 40/20 mm Hg (mean, 27), and a pulmonary capillary wedge pressure of 20 mm Hg. Following several hours of assistance, the hypotension was reversed, the pulmonary artery pressure had fallen to 30/11 mm Hg (mean, 16), and the pulmonary

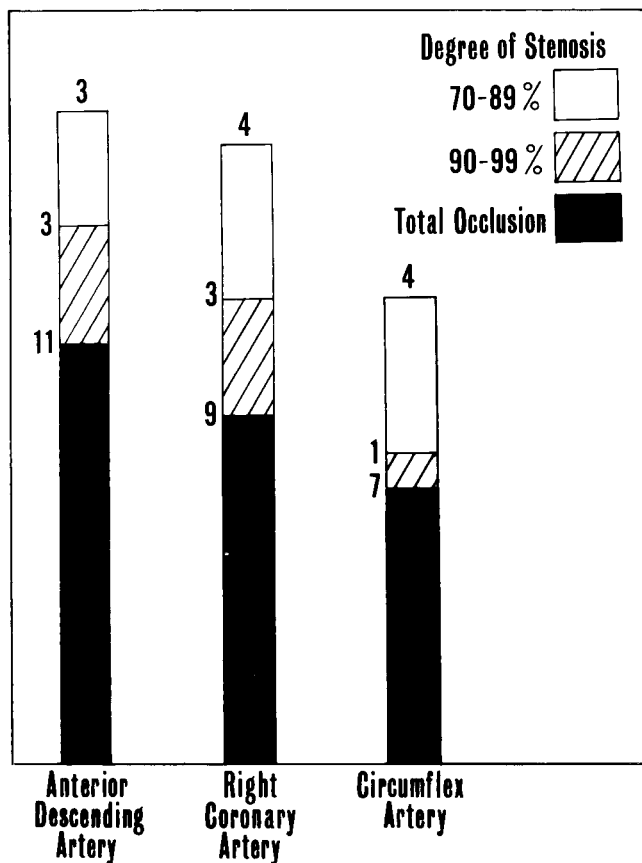
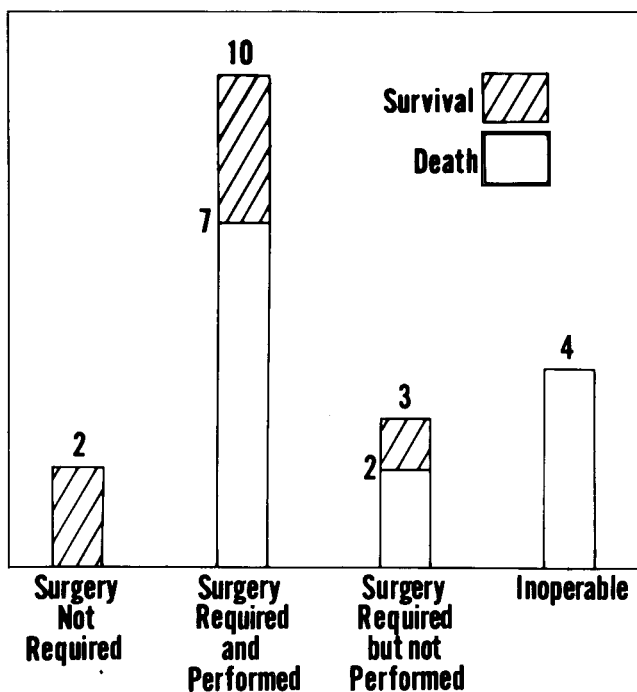


Fig 2.—Distribution and degree of severity of serious occlusive disease involving major branches of coronary arteries.

Fig 3.—Results in 19 patients who underwent catheterization to determine need for and feasibility of cardiac surgery.



Results of Patients Undergoing Cardiac Surgery				
Patient	Surgical Procedure			
	Bypass Surgery	Infarctectomy	Repair of Septal Defect	Mitral Valve Replacement
Survivors				
1	Diagonal	No	Yes	No
2	Right coronary	Yes	No	No
3	Right coronary, obtuse marginal, anterior descending	No	No	No
Nonsurvivors				
4	Anterior descending	No	No	No
5	No	Yes	No	Yes
6	No	Yes	No	No
7	Right coronary	Yes	No	No
8	Right coronary	Yes	No	No
9	Anterior descending	No	Yes	No
10	Right coronary, anterior descending	No	No	No

capillary wedge pressure to 13 mm Hg. The second patient had an initial systolic blood pressure of 80 mm Hg, a pulmonary arterial pressure of 40/24 mm Hg (mean, 28), and a pulmonary capillary wedge pressure of 21 mm Hg. After six hours of IABP, all pressures had returned to normal. The strong positive response to assistance suggested adequate reserve and a good chance of survival without surgery.

The ventriculogram of each patient was examined to evaluate the contractility of various segments of the chamber. Segmental akinesia with associated Q waves and segmental dyskinesia were considered evidence of necrotic or scar tissue not recoverable by coronary artery bypass surgery. Akinesia or dyskinesia involving more than two of the five segments (40% or more of the chamber circumference) was considered a contraindication to surgery. A low ejection fraction was in itself not considered an absolute contraindication; one patient with an ejection fraction of 10% was considered a candidate for surgical therapy. Mechanical defects, including localized areas of infarction, rupture of the interventricular septum, and serious mitral regurgitation, were considered amenable to surgery when sufficient functioning or salvable myocardium existed.

Coronary bypass surgery was considered applicable if there was diameter narrowing greater than 70% in the proximal portion of a coronary vessel with adequate distal runoff. The distal runoff was evaluated in terms of the size of the territorial distribution and the appearance of the distal lumen; the distal lumen had to be at least 1 mm in diameter with a relatively smooth margin, and the distal vessel had to opacify well with an adequate rate of emptying.<sup>8,9</sup> Correlation of myocardial viability by ventricular kinetics at ventriculography and by electrocardiography was made in the segments of myocardium supplied by the vessels in question. Bypass surgery was not attempted in vessels supplying nonviable tissue.

Thirteen patients were judged to be candidates for sur-

gery including mitral valve replacement, repair of a ruptured interventricular septum, infarctectomy, coronary artery bypass, or combinations of these procedures. Four patients' conditions were considered inoperable because of a lack of reconstitution of distal vessels following total occlusion of major coronary arteries. There was akinesia or dyskinesia in corresponding ventricular segments, and the amount of noncontracting myocardium exceeded 40% of the left ventricular circumference. The amount of viable myocardium, as determined on the basis of these considerations, was thought to be inadequate to sustain life.

## RESULTS

Data from 19 patients who underwent catheterization to determine whether cardiac surgery was indicated are shown in Fig 3. Two patients thought to have a good prognosis without surgery were gradually weaned from diastolic assist and were discharged from the hospital. They have returned to work and have survived for 17 and 13 months, respectively, since being discharged from the hospital. Ten patients underwent surgery; three survived (Table). One died 18 months after surgery, while two have survived for 18 months and are currently well and at work. Three other patients were considered candidates for surgical treatment but did not have surgery. One had irreversible brain damage following multiple episodes of ventricular fibrillation, the second died of an arrhythmia on the way to the operating room, and the third patient refused surgery. The patient who refused surgery was eventually weaned from diastolic assist and was discharged from the hospital. He died at home four weeks after catheterization. Four patients were considered inoperable; their conditions steadily deteriorated and all four died.

## COMMENT

The challenge to the clinician who undertakes balloon pumping for patients in acute circulatory failure after acute myocardial infarction is to determine which of them will require surgery to survive and which of them cannot survive because of loss of a critical amount of myocardium. It is generally agreed that cardiogenic shock occurs after loss of function of approximately 30% of the left ventricular myocardium due to severe ischemia or cellular necrosis. In this situation, death usually occurs when 40% or more of the left ventricular myocardium is destroyed.<sup>10</sup> Diastolic augmentation can temporarily, and in some cases permanently, preserve a critical margin of viable myocardium by lowering the work requirement of the left ventricle and by reducing its oxygen demand. These effects of diastolic augmentation may be temporary, and tissue recovery may be dissipated when it is terminated. These considerations imply that revascularization should be attempted soon after the insult in order to preserve tissue viability.

In this study, the physiologic response to pumping and ventricular angiography were used as indicators of the amount of viable myocardium remaining. These modalities were relatively accurate in assessing the amount of

"recoverable" tissue. Two patients, predicted to have enough myocardium to survive without pumping, did indeed survive. Of 17 patients predicted not to have enough functioning myocardium to survive, seven did not have surgery and six died in the hospital. One patient was discharged, only to die four weeks following catheterization. Ten patients had surgery and three survived, most likely because bypass surgery and repair of mechanical defects salvaged enough myocardium to sustain life. Other investigators have reported similar survival rates.<sup>11-14</sup> These results, if confirmed in an adequately large number of patients, represent a great improvement over balloon pumping alone, although still better selection of surgical candidates is possible. The limiting factor appears to be inability to accurately distinguish ischemic from dead tissue.

At present, determination of segmental contractility at ventriculography is our most accurate method of predicting viability. Noncontractile segments, however, may still be viable although ischemic. The performance of ventriculography before and after administration of nitroglycerin or catecholamines, and determination of contractility before and after premature beats, have proved helpful in identifying ischemic tissue inasmuch as these procedures "potentiate" or "unmask" residual myocardial contractility.<sup>15-17</sup> This differentiation is extremely important, not only in identifying vessels that require bypass surgery, but also in assessing suitable candidates for infarctectomy. In our studies, four of five patients in whom infarctectomy was performed died. This disappointing experience may in part have been due to overestimation of the amount of remaining viable myocardium. Glass et al<sup>18</sup> reported that if more than 30% of the left ventricular wall is removed, the chance of survival is extremely small. Glass et al,<sup>18</sup> Heimbecker et al,<sup>19</sup> and Jude et al<sup>20</sup> also found, however, that ventricular function was improved and survival rates rose when infarcts amounting from 10% to 25% of the left ventricular wall were excised in animal experiments. The survival rates were thought to be increased because of restoration of the Starling mechanism<sup>21</sup> and removal of foci of electrical irritability.

If differentiation of ischemic from nonviable muscle can be improved by development of better angiographic, electrophysiologic, and isotope techniques, then some patients formerly denied surgery will become candidates, while those without adequate viable myocardium will not be subjected to futile procedures.

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## Discussion

WILLIAM S. BLAKEMORE, MD, Toledo, Ohio: I believe this presentation illustrates a frontier in medicine today. Would Dr Cascade give us some impression of where we are going, especially with radiographic techniques?

We have the ability now to perform many radioisotope studies, such as those reported here. The equipment is expensive to install, but no doubt provides different information that we are unable to obtain with other noninvasive techniques. There are new radiographic methods for tomography that add further information. Experience with these techniques will demonstrate their clinical usefulness.

In this group of patients with a mortality of almost 100%, physiologic measurements may permit more effective early treatment, as the authors have demonstrated. We seek even better alternatives, but the results are not worse than early results were in operative procedures now commonly performed with low mortalities. Some persons at this meeting can remember the early results of the techniques for mitral commissurotomy: the mortality was

high. The high mortality in this group should serve as an incentive to further effort despite the dissatisfaction with results from present-day methods.

DR CASCADE: I must emphasize that the survival rate in this group of patients is in the range of 15%. With the small number of patients who have emergency corrective cardiac surgery, it appears as though the survival rate has been increased to 30% or 40%. A large number of patients will have to be operated on to obtain a more statistically valid conclusion as to the efficacy of surgery.

Better noninvasive methods that will evaluate the amount of myocardial injury are being developed. With these bedside procedures, perhaps we will be able to predict in which patients delayed cardiogenic shock will develop. Perhaps then we will be able to operate on these patients before the onset of shock. At the present time, isotope studies of the heart appear to be the promise of the future in this area.